DOCUMENT RESUME

ED 473 042 SP 041 376

AUTHOR	Cole, Donna J.; Ryan, Charles W.; Tomlin, James A.
TITLE	Inquiry Based Science: A Constructivist Approach in Teacher Education.
PUB DATE	2003-00-00
NOTE	22p.
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	*Constructivism (Learning); Cooperative Planning; Elementary Secondary Education; Higher Education; Inquiry; *Interdisciplinary Approach; *Mathematics Education; *Preservice Teacher Education; Professional Development Schools; *Science Education
IDENTIFIERS	*Joint Appointments

ABSTRACT

This paper presents an integrative model for developing collaborative academic structure between education and science/mathematics content departments. The model was developed through active partnerships with selected professional development schools (PDS PreK-12), College of Science and Mathematics faculty, and teacher educators in a professional College of Education. Survey results indicate that joint faculty appointments between academic departments and education, in tandem with clinical faculty appointments for PreK-12 teachers, lead to strong inquiry-based science courses for preservice teacher education candidates. Joint teaching of science courses was aligned with a constructivist approach and resulted in inquiry based science/mathematics courses taught to interns at PDS. Faculty with joint appointments between education, science, and mathematics successfully achieved tenure. (Contains 23 references.) (SM)

SP SPTR
REQ 0060

INQUIRY BASED SCIENCE: A CONSTRUCTIVIST APPROACH IN TEACHER EDUCATION

BY

DR. DONNA J. COLE, PROFESSOR AND DIRECTOR OF FIELD EXPERIENCES,
COLLEGE OF EDUCATION AND HUMAN SERVICES, WRIGHT STATE UNIVERSITY
DAYTON, OHIO 45435

DR. CHARLES W. RYAN, PROFESSOR AND DIRECTOR OF GRADUATE PROGRAMS,
COLLEGE OF EDUCATION AND HUMAN SERVICES, WRIGHT STATE UNIVERSITY
DAYTON, OHIO 45435

DR. JAMES A. TOMLIN, ASSOCIATE PROFESSOR, COLLEGE OF EDUCATION AND
HUMAN SERVICES, WRIGHT STATE UNIVERSITY
DAYTON, OHIO 45435

Abstract

This paper presents an integrative model for developing collaborative academic structure between education and science/mathematics content departments. The model was developed through active partnerships with selected professional development schools (PDS Pre K - 12), College of Science and Mathematics faculty and teacher educators in a professional College of Education. Results indicate that joint faculty appointments between academic departments and education, in tandem with clinical faculty appointments for Pre K - 12 Teachers lead to strong inquiry based science courses for pre-service teacher education candidates. Joint teaching of science courses was aligned with a constructivist approach and resulted in inquiry based science/mathematics courses taught to interns at PDS. Faculty with joint appointments (N=8) between Education, science and mathematics successfully achieved tenure.

Introduction

Historically, the Colleges of Education and the Arts and Sciences have failed to interact supportively in the preparation of teachers. This paper presents a model and process for shared decision-making among teacher education faculty, Pre-kindergarten through grade 12 (PreK-12) educators and the Science and Mathematics faculty in the preparation of quality educators. Wright State University (WSU), part of the National Network for Educational Renewal (NNER), was selected in 1994 as one of 18 institutions whose process for teacher education reform made extensive use of PreK-12 sector involvement. This university successfully received re-accreditation by the National Council for the Accreditation of Teacher Education (NCATE) in the Fall of 2001. Several joint faculty appointments between the College of Education and Human Services (CEHS) and the College of Science and Mathematics (COSM) served as pivotal factors, insuring that learned society guidelines are infused into content courses for early childhood, middle childhood and secondary pre-service students. The following outlines our path to quality science education.

WSU is immersed in change; change in our teacher preparation program as the state of Ohio moves from teacher certification to licensure in the fall of 2002. Change in our courses as we continue to strive to develop science content courses that incorporate "best practices" and effective science teaching pedagogy in alignment with a constructivist philosophy. Change also in our roles as college faculty as we move from beginning assistant professors to more seasoned, "connected", knowledgeable facilitators of the simultaneous renewal and partnershipping efforts within the partnership schools in which we work.

Wright State used a process model to plan and articulate the simultaneous renewal of the education of educators and the PreK-12 sector. The College of Education and Human Service at WSU, has formal involvement in this ongoing process to bring about systemic change to PreK-12 and teacher education since January, 1992. Over 430 representatives of the PreK-12 sector, business, human service agencies, university, military, and others, provided input on the changes needed to create a new culture for the collaborative education of educators who are responsive to society's needs (Milestone One Report, 1993 a, Milestone Two Report, 1994 b).

Individuals from the PreK-12 sector who work with this initiative are classroom teachers and administrators representative of a number of school systems within the Dayton metropolitan region that WSU serves. With the amount of criticism aimed at the public schools and the growing concern about teacher preparatory programs, educators can no longer work in isolation. The college faced this challenge and invited not only the PreK-12 sector to join hands in problem solving, but turned to the University at large to work collaboratively in building a program that prepares more qualified pre-service teachers and renew PreK-12 and higher education faculties and administrators.

The concept of "simultaneous renewal" of both PreK-12 and teacher education surfaced as an essential component of our advancement efforts. No partnership can exist where only one partner grows and benefits. As Goodlad establishes in *Educational Renewal: Better Teachers, Better Schools* (1994), working together must be mutually advantageous.

Wright State's redesigned teacher education curricula, a graduate post baccalaureate professional school model for middle school and high school educators, is aligned with six formally established partnership school districts. Classroom teachers, school administrators, arts and sciences faculty, education and human services faculty, and community representatives serve

as integral collaborators in this ongoing process for renewal. All partners are actively involved in professional development activities and on advisory committee structure. The CEHS' agenda focuses our energy and resources in alignment with the College's conceptual framework: *"To foster the art and sciences of teaching."* Partner schools and districts also articulated an identified agenda of specific goals and improvements. Partnershipping goals focus on moving the agenda of both parties forward (Clark, 1997). In practice, seven advisory committees met on a bi-weekly schedule to discuss policy and procedural issues related to facility use, Intern assignments, tenure and promotion issues, subject content teaching approaches and state/professional standards as melded into curriculum.

University administrators promote bridges between the various colleges to more effectively integrate the separate pieces of the teacher education enterprise. Nowhere is this initiative more visible than in interactions between COSM and CEHS. Over the last ten years, the university has appointed eight joint appointment faculty to the Department of Teacher Education, with partial assignment to respective departments in COSM. These individuals, as well as several regular COSM faculty and in-service teachers formed the nucleus of a science education team. This core-teaching faculty nucleus is charged with responsibility to reduce institutional barriers (lack of joint course planning) and develop inquiry based science courses aligned with professional society standards, e.g. American. These barriers traditionally represented impediments to inter-department collaboration towards improved pre-service and in-service professional development and pedagogical practice.

The overall process of developing collaborative teaching programs between CEHS and COSM at WSU represent an evolutionary process. To understand how WSU arrived at the

position that exists today requires understanding historical perspectives of growth and change in CEHS.

In the early 1990's CEHS taught science courses using a combination of adjunct and instructor faculty. In 1992, a situation arose within CEHS with the retirement of several instructors who proved difficult to replace with adjunct faculty. Coupled with this dilemma was public concern regarding the educational preparation of students in grades PreK-12. Public perception implied that teachers were not prepared sufficiently in the content of many disciplines, especially mathematics and science. Since the United States and Ohio economies were becoming more technologically based and requiring a steady supply of graduates trained in the areas of mathematics and science, it was imperative that newly trained teachers be well prepared in the content of mathematics and science to encourage young students who have a career interest in these areas.

At WSU, the Deans of CEHS and COSM arrived at a unique solution to the conundrum. Courses specifically aimed at K-9 education majors would be taught in COSM by faculty who held at least a Masters Degree in the subject area. When this solution was first proposed, a potential difficulty was faced by CEHS, namely, the loss of student credit hours. WSU is a state funded university and as such qualifies for Board of Regents subsidy that is based upon several factors, one of them being student full-time credit hours. Discussions with the Provost helped alleviate that problem. Since the state subsidy is greater for courses taught in COSM than in CEHS, the university, overall, would gain additional subsidy monies. CEHS would be held financially and "staff" harmless for the loss of student credit hours since the university would be the ultimate beneficiary of the additional subsidy monies.

CEHS and COSM faculty collaborated through joint meetings to redesign the science and mathematics teacher preparation programs. This required the development of a new educational curriculum, that included hiring joint appointed faculty. As described above, it was decided that both CEHS and COSM would hire mathematics and science education faculty and as such, they would hold joint appointments in the departments of Teacher Education and Science and Mathematics in COSM. Currently there are eight dual appointees. On hiring these joint faculties specific expectations were presented. Of principal interest to the joint appointment of science and mathematics educators were issues related to promotion and tenure. It was decided that:

a) The College in which the faculty principally resided (>50% appointment) would be the College, which would originate the promotion and tenure document. The College in which the science and mathematics educator had a <50% appointment would review the document and make relevant comments, but would only vote on the faculty's suitability for promotion and tenure at the university level.

b) Criteria for promotion and tenure - The Dean of COSM was insistent that there be only one set of by-laws for each department. Thus, sciences and mathematics educators would have to meet the minimum requirements for promotion and tenure that were set down for other members of the Geology, Biology, Chemistry or Mathematics Departments. Latitude in the area of scholarship for science and mathematics educators was broadened. Instead of a minimum of four papers published in peer-reviewed journals, which is required for regular science and mathematics faculty, science and mathematics education faculty would have their scholarship evaluated in a broader sense. Science and mathematics education faculty must have a minimum of two papers published in peer-reviewed journals. Additionally, they may demonstrate a significant record of successful grant activity. Service is expected in the COSM, but unfortunately, it is rarely given much consideration at promotion and tenure time for regular science and mathematics faculty. The requirement of field service for science and mathematics education faculty with respect to monitoring prospective teachers as they complete field experiences was noted and accepted.

c) Departmental Stature - Since many of the joint appointed science and mathematics education faculty in COSM regularly teach courses in the discipline, in addition to the content-based education courses, they were welcomed as regular department faculty. Unfortunately, a few COSM faculty consider themselves discipline purists and may subconsciously look upon the sciences and mathematics educators as "second-class citizens". With COSM's Dean and Chairs' support, this archaic approach is slowly disappearing, as more of the science and mathematics educators become tenured in

COSM. As of today, five of the jointly appointed science and mathematics education faculty who have been considered for promotion and tenure have been approved without difficulty.

In sum, the following positive benefits resulted from the creation of the jointly appointed science education faculty and the teaching of science courses:

- The science content background in teacher preparation programs has been strengthened.
- A closer working arrangement between faculty of the College of Education and Human Services, and College of Science and Mathematics has developed.
- The frequent exchange of information between faculty in the CEHS and COSM has fostered a better understanding of the goals of the two colleges. Ultimately, courses are in place for better-prepared teachers in science and mathematics and students in the schools are the ultimate winners of this program.

Integrating Science Standards with Science Content

The State of Ohio requires all entry level licensed educators to successfully pass PRAXIS III. PRAXIS III is a performance-based assessment constructed around four domains and nineteen criteria (see Figure 1).

Teacher Performance Assessments: Assessment Criteria
From: Educational Testing Service,(1994).

Domain A – Organizing Content Knowledge for Student Learning	**Domain C** – Teaching for Student Learning
A1: Becoming familiar with relevant aspects of students' background knowledge and experiences A2: Articulating clear learning goals for the lesson that are appropriate for the students A3: Demonstrating an understanding of the connections between the content that was learned previously, the current content, and the content that remains to be learned in the future A4: Creating or selecting teaching methods, learning activities, and instructional materials or other resources that are appropriate for the students and that	**C1: Making learning goals and instructional procedures clear to students** C2: Making content comprehensible to students C3: Encouraging students to extend their thinking C4: Monitoring students' understanding of content through a variety of means, providing feedback to students to assist learning, and adjusting learning activities as the situation demands

are aligned with the goals of the lesson A5: Creating or selecting evaluation strategies that are appropriate for the students and that are aligned with the goals of the lesson	C5: Using instructional time effectively
Domain B – Creating an Environment for Student Learning	**Domain D** – Teacher Professionalism
B1: Creating a climate that promotes fairness B2: Establishing and maintaining rapport with students B3: Communicating challenging learning expectations to each student B4: Establishing and Maintaining consistent standards of classroom behavior B5: Making the physical environment as safe and conducive to learning as possible	**D1: Reflecting on the extent to which the learning goals were met** D2: Demonstrating a sense of efficacy D3: Building professional relationships with colleagues to share teaching insights and to coordinate learning activities for students D4: Communicating with parents or guardians about student learning

At Wright State University we believe that the Praxis III criteria, designed to be generic to all disciplines, can be enhanced by content mandates from the various learned societies. Science was the first content area where alignments with the Praxis III four domains were attempted (see Figure 1). The National Science Foundation report (1996) entitled, "Shaping the Future: New Expectations for all in Understanding Education in Science, Mathematics, Engineering and Technology;" provided key summations which guided our collaborative work:

- College science and math programs should be refocused in order to better educate the 80 percent of students who do not major in the science discipline.
- All students should learn these subjects by direct experience with the method and processes of inquiry.
- Any sustained national effort to improve science and math achievement eventually must address the quality of teacher education at the undergraduate level.

- Few teachers, particularly those at the elementary level, experience any teaching that stresses the skills of inquiry and investigation; they simply never experience those methods in their teaching.

- Faculty must actively engage their students preparing to be PreK-12 teachers (as well as others) by assisting them to learn not only science facts, but also the methods and processes of research, what scientists and engineers do, how to make informed judgements about technical matters, and how to communicate and work in teams to solve complex problems.

- While some institutions are already making the changes needed to help them meet that goal, most are not.

To assist teachers in developing pedagogical skills, curriculum knowledge and attitudes and dispositions necessary to educate all students, university and/or site based courses and partner school learning activities are constructed to exemplify good science teaching. These courses demonstrate the content and pedagogy of exemplary teaching that recent science education standards state are necessary. Within these classes valuable and practical learning episodes occur to support excellence and equity for pre-college students. Accordingly, we now have early and middle childhood science programs which not only strive to achieve science content understandings congruent with the *Ohio State Science Model* (1994), the National Research Council's *National Science Education Standards* (NRC, 1996), and the American Association for the Advancement of Science *Benchmarks for Science Literacy* (AAAS, 1993), but also seek to impart pedagogical content knowledge specific to individual science disciplines. Moreover, student understandings are acquired within an active and constructivist inquiry-based framework designed to enable students to witness science and science education faculty "walking the walk" and not just "talking the talk". Constructivist integration into science content has required changes in teacher practice and more reliance on student "hands on science."

Method

To obtain a measure of the relationship between science content taught to pre and in-service science teachers, a number of instruments were administered to assess conceptual understanding, confidence and beliefs as they related to a constructivist standards-based classroom. The relationship between these scales was obtained through the Wilcoxian Signed Rank Test of Differences for non-parametric data (1956). The Constructivist Learning Environment Survey (Taylor and Fraser, 1991, CLES), containing six sub-scales and a Teacher Belief Survey (2001) were administered to 24 participants in an in-service science mentor development program. The Constructivist Learning Environment Survey (CLES) is an instrument designed to measure the extent to which a teacher values a "constructivist" orientation within the school science/mathematics learning environment.

The Science Mentor Professional Development Institute is an in-service teacher professional development program and its purposes include: First, to improve teachers' conceptual understandings of national and state standards. Second, to improve teachers' confidence in their ability to implement standards-based curriculum and pedagogy. Third, to change teachers' beliefs, attitudes and values as they relate to a constructivist/ standards-based classroom environment, and finally to change teachers' beliefs, attitudes, and values as they relate to their mentoring efficacy and outcome expectancy.

Statistics generated via a Wilcoxian Signed Rank Test (Guilford, 1956) indicate a significant change in teacher beliefs after participating in the Science Mentor Development program. Teachers were more likely to believe that all students can learn to think scientifically. The program also increased the probability that a teacher would believe they should consistently use activities that require students to do original thinking. Teachers were more likely to believe

that it is not whether students answer science questions correctly, but rather that they can explain the answers that they did give. Additionally the program fostered the belief that learning by all students is enhanced by incorporating the contributions of different cultures.

This study utilized a modified versions of the CLES where teachers were asked items about their students attitudes and perceptions. These items of the CELS were utilized in the Salish Research Project (1995), a national collaborative conducted in an effort to ascertain knowledge about the relationships between secondary science and mathematics teacher preparation, new teacher knowledge, beliefs, and performance; and student learning outcomes (Salish I, 1995).

Wilcoxian Signed Rank Test for Teacher Belief Statements

Questions	Z-Value	P-value
All students can learn to think scientifically	-2.521	.0117*
Should consistently use activities which require students to do original thinking	-2.201	.0277*
Important issue is not whether answers to science questions are correct, but if kids can explain their answers	-2.803	.0051*
Learning for all students is enhanced by incorporating the contributions of different cultures	-2.023	.0431*
To manage a class of students who are using hands-on/manipulative materials	-2.201	.0277*
To use cooperative learning groups	-2.366	.0180*
To implement inquiry or discovery learning	-2.521	.0117*
To present applications of science concepts	-2.521	.0117*
To phrase questions to encourage more open-ended investigations	-2.521	.0117*

To use computers as an integral part of science instruction	-3.516	.0004*
To teach groups that are heterogeneous in ability	-1.775	.0759*
To use performance-based assessment	-3.180	.0015*
To use portfolios to assess student progress in science	-3.296	.0010*
Encourage participation of females in science	-2.023	.0431*
To involve parents in the science education of their children	-3.180	.0015*

Note (*p < .05, N=24)

The six sub-scales of the modified Constructivist Learning Environment Survey are as follows:

The Personal Relevance Scale was designed to measure the extent to which teachers feel that their students should perceive the relevance of school science to their out-of-school lives. The questions this scale asks are: Does the teacher perceive that their students should experience the relevance of school science to their everyday interests and activities? Does the teacher perceive that their students should use their everyday experiences as a meaningful context for their development of their formal scientific knowledge?

The Scientific Uncertainty Scale was designed to measure the extent to which teachers feel that their students should perceive science to be an uncertain and evolving activity embedded in a cultural context and embodying human values and interests. The questions that the scale asks are: Does the teacher perceive that their students should perceive scientific knowledge as evolving and provisional? Does the teacher perceive that their students should perceive scientific knowledge as shaped by social and cultural influences and arising from human values and interests?

The Critical Voice Scale was designed to measure the extent to which teachers feel that their students should exercise a critical voice about the quality of their learning activities. The questions the scale asks are: Does the student perceive that it is legitimate and beneficial to question the teacher's pedagogical plans? Does the student perceive that it is legitimate and beneficial to express concerns about any impediments to their learning?

Wilcoxian Signed Rank test for Constructivist Learning Envirionment Survey (CLES)

Sub-scale	**Z-Value**	**P-value**
Personal Relevance	0.000	>.9999
Scientific Uncertainty	-0.357	.7213
Critical Voice	-2.028	.0425*
Shared Control	-2.223	.0262*
Student Negotiation	-1.782	.0747
Attitude	-0.840	.4008

Note (*p < .05, N=24)

The Shared Control Scale was designed to measure the extent to which the teacher feels that their students should be involved in the management of the classroom learning environment. The questions the scale asks are: Does the teacher perceive that their students should design and manage their own learning activities? Does the teacher perceive that their students should be determining and applying assessment criteria? Does the teacher perceive that their students should negotiate the social norms of the classroom?

The Student Negotiation Scale was designed to measure the extent to which the teacher feels that their students should interact verbally with other students for the purpose of their scientific knowledge within the consensual domain of the classroom. The questions the scale asks are: Does the teacher perceive that their students should be engaged in explaining and justifying their newly developed ides to other students? Does the teacher perceive that their students should be engaged in making sense of other students' ideas and reflecting on the viability of their ideas? Does the teacher perceive that their students should be engaged in reflecting critically on the viability of their own ideas?

The Attitude Scale was designed to measure the teacher's interpretations of the students to the science classroom. The questions the scale asks are: Does the teacher perceive that their students should enthusiastically anticipate the activities? Does the teacher perceive that their students should value the sense of worthwhileness of the activities? Does the teacher perceive that their students should value the impact of the activities on student interest, enjoyment and understanding?

These programs also aided in teacher confidence. When participants were administered the Teacher Belief Survey their responses indicated that those who participated in the program ranked higher in confidence in several areas. For example, teachers felt more able to manage a class of students who are using hands-on/manipulative materials and to use cooperative learning groups. Compared to other populations of teachers, those who participated in the Science Mentor Professional Development Institute program felt more able to implement inquiry or discovery learning, and also felt more confident in their ability to present applications of science concepts. Changes in teacher confidence were also evident in that the teachers felt more able to phrase questions to encourage more open-ended investigations.

Some of the other areas where there was evidence of increased teacher confidence included use of computers as an integral part of science instruction, increased confidence was also found in that teachers felt more able to teach groups that are heterogeneous. Their confidence in use of performance-based assessments increased as well as their ability to use portfolios to assess student progress in science. Other changes in teachers' confidence were that teachers felt more able to encourage participation of females in science. Finally teacher confidence improved so that they felt more able to involve parents in science education of their children. However, survey methodology when used to assess teacher perceptions and use of constructivist pedagogy fails to observe actual classroom practice and does not assess other populations of science teachers who may use other approaches to teaching science.

Results and Discussion

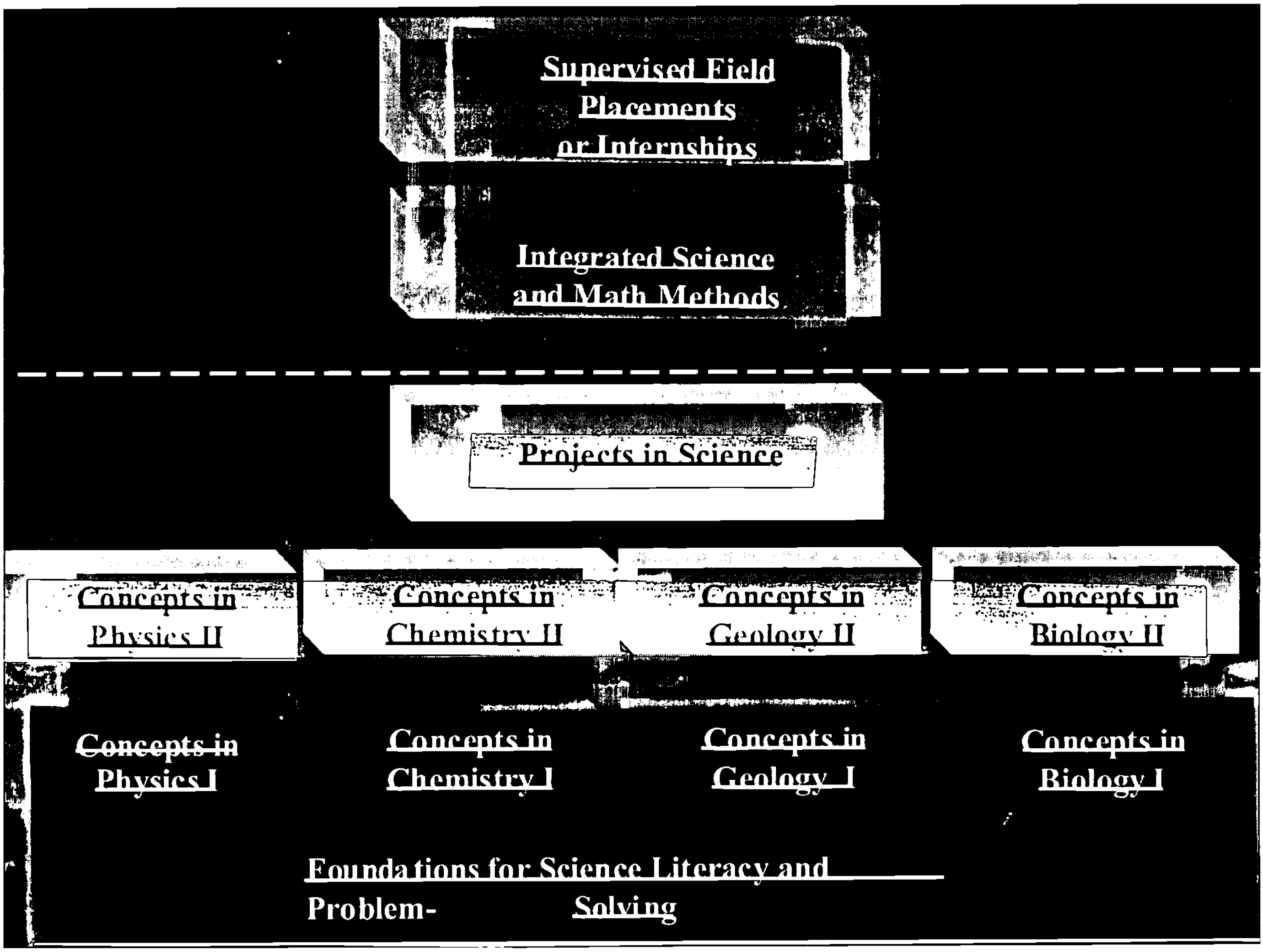
Working with both pre-service and now in-service teachers in science courses creates greater potential for blending science education theory with best teaching practices in the partnership classroom; thus benefiting students and teachers alike. Presently, CEHS is exploring ways to match pre-service teachers' experiences from the initial required observational phase to on-site internships, and student teaching with in-service teachers who are immersed in our expanded science course offerings. This process requires finding strategies to overcome many of the traditional ways in which school districts place pre-service teachers in classrooms. This is proving to be another challenge for change, change within the traditional culture of the school districts and the university system. CEHS' thinking reflects Michael Fullan's "Ready, Fire, Aim" approach, we keep moving forward even when the path is not clearly visible in front of us (Fullan, 1998). Some of that 'surefootedness' comes from the college's years of learning to deal

successfully with the constancy of ambiguity and change while proceeding forward. However, CEHS is confident because the strategy has proven successful for implementing and institutionalizing our ever-changing science education program.

Two example courses include a content biology course developed and taught by science educators with strong content preparation and a content specific, science methods course developed and taught in collaboration with scientists and science educators with extensive pre-college science teaching experience. Assessment issues related to classroom performance are evaluated within a context that is reflective, authentic and congruent with performance-based state licensure requirements, as well as learned society content standards for NCATE accreditation.

The faculty in science education developed a conceptual framework for undergraduate elementary pre-service students at WSU. The framework contains six levels. The first level consists of a foundational course aimed at developing initial science literacy and problem solving. The second level involves four conceptual units in physics, chemistry, geology and biology. The third level builds on level two by advancing knowledge and skills in the four science disciplines (physics, chemistry, geology and biology). The fourth level requires students to complete projects in science. The final two levels involve post baccalaureate science teaching application. Level five integrates math and science methods, while a capstone level includes supervised field and intern placements (Figure 2). Being a faculty member in two colleges is perhaps the best training for us in learning to cope with the ebb and flow of ambiguity and the tension of differing cultures at work in arts and sciences, CEHS and at professional development schools.

Science Content for integrating professional standards into teacher preparation.



Concluding Comments

This flexibility and openness to ever changing ideas and methodologies permits us to effectively develop a science program based on the State and National Science Education Standards (NSES) and to be responsive to the science technology needs of in-service teachers. Further, CEHS changes and developments include modifying our science courses to allow

classroom teachers opportunities to learn content while updating their understanding of science education pedagogy

The complexity of our inquiry suggests that joint teaching of science courses raises issues of pedagogical practice between science purists and education faculty who deal with the reality of application in K-12 schools. For the past four years we sought to apply standards based content to the training of teachers, but noted that the philosophical disagreements among colleagues on the dimensions of effective K-12 science/mathematics teaching and how science is taught at the university level compounds the analysis. Determining what is "best practices" became very elusive in our staff discussion related to determining course content.

In sum, our conclusions are derived from a set of multiple interactions with colleagues in the content disciplines and the data acquired from a group of in- and pre-service teachers seeking to develop skill in science/mathematics content delivery.

Acknowledgements

The authors wish to thank Andrew Zircher, Graduate Assistant, for assistance in formatting the statistical tables and the CEHS Deans Office for financial support in conducting this study.

REFERENCES

American Association for the Advancement of Science (1993). Benchmarks for science literacy. New York, NY: Oxford University Press.

Antony, J.S. and Raveling, Joyce (1998, November). A comparative analysis of tenure and faculty productivity: Moving beyond traditional approaches. Paper presented at the Association for the Study of Higher Education annual meeting, Washington, D.C.

Benchmarks for Science Literacy, (1989). American Association for the Advancement of Science. Washington, D.C.

Chait, R.P. (1994). Make us an offer: Creating incentives for faculty to forsake tenure. (ERIC Report No.: Ej477905). Washington, DC: National Center for Research in Higher Education.

Clark, R.W. (1997., Professional development schools: policy and financing Washington, D.C.: AACTE Publications.

Enocks, L.G. and Riggs, I.M. (1990). Further development of an elementary science teaching scale efficacy belief instrument; A pre-service elementary scale. School Science and Mathematics, 90, 695-706.

Fullan, M. (1998, April). What's worth fighting for? Paper presented at the Vernon Anderson Lecture Seminar. College Park, MD: University of Maryland.

Goodlad, J. (1994). Education renewal: Better teachers, better schools. San Francisco, CA: Jossey-Bass Publishers.

Goodlad, J. (1990). Teachers for out nation's schools. San Francisco, CA: Jossey-Bass Publishers.

Guilford, J. P. (1956). Fundamental Statistics in Psychology and Education. New York, McGraw-Hill Book Co.

Harland, T. (2002). Zoology students' experiences of collaborative enquiry in problem-based learning. Teaching in Higher Education, 7 (1), pp. 1-15.

Milestone one: A synthesis report (1993a). College of Education and Human Services, Wright State University, Dayton, Ohio 45435.

Milestone two: A synthesis report (1994b). College of Education and Human Services, Wright State University, Dayton, Ohio 45435.

National Research Council (1996). National Science Education Standards. Washington, D.C.: National Academy of Sciences.

National Science Foundation (1996). Shaping the future: New expectations for all in understanding education in science, mathematics, engineering and technology. Washington, D.C. Author.

Ohio State Board of Education (1994). Science: Ohio's Model Competency-Based Program. Columbus, OH. Author.

Rice, C. (1999, July). Transformation of Faculty Work. Paper presented at the Council of Graduate Schools Summer Workshop, Portland, Maine.

Salish, I. Research Project (1995). Measurement package for year three data collection. Iowa City, IA: University of Iowa. Author.

Sizor, T. (1992). Horace's school: Redesigning the American high school. (New York; NY: Houghton Mifflin Company.

Shulman, L. (1988, November). A union of insufficiencies: Strategies for teacher assessment in a period of educational reform, Educational Leadership, 36-41.

Shulman, L., Bird, T. and Haertel, E. (1989). Toward alternative assessments of teaching: A report of work in progress. Stanford University, CA: Teacher Assessment Project.

Taylor, P.C. and Fraser, B.J. (1991). CLES: An instrument for assessing constructivist learning environments. Paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST). Fontane, WI: The Abbey.

Teacher Belief Survey. (2001). Chaple Hill, NC: Horizon Research, Inc. Author.

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

ERIC®

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: INQUIRY BASED SCIENCE: A CONSTRUCTIVIST APPROACH IN TEACHER EDUCATION	
Author(s): DONNA J. COLE	
Corporate Source: COLLEGE OF EDUCATION AND HUMAN SERVICES, WRIGHT STATE UNIVERSITY, DAYTON, OHIO 45345	Publication Date: 1/7/03

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1 ↑ [X]	Level 2A ↑ [ ]	Level 2B ↑ [ ]
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) *and* paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here,→ please

Signature: Donna J. Cole	Printed Name/Position/Title: DONNA J. COLE PROFESSOR OF EDUCATION	
Organization/Address: 3640 COL. GLENN HIGHWAY WRIGHT STATE UNIVERSITY DAYTON, OH 45435	Telephone: 937-775-3998	FAX: 937-775-2099
	E-Mail Address: DONNA.COLE@WRIGHT.EDU	Date: 1/14/03

(over)

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, *or*, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:
Address:
Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:
Address:

V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

ERIC Clearinghouse on Teaching
and Teacher Education
1307 New York Ave., NW
Suite 300
Washington, DC 20005-4701

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

ERIC Processing and Reference Facility
4483-A Forbes Boulevard
Lanham, Maryland 20706

Telephone: 301-552-4200
Toll Free: 800-799-3742
FAX: 301-552-4700
e-mail: info@ericfac.piccard.csc.com
WWW: http://ericfacility.org